

Protecting Cotton From Insects and Plant Diseases

BY F. A. FENTON AND K. STARR CHESTER

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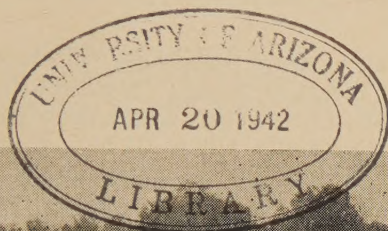
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OKLAHOMA AGRICULTURAL EXPERIMENT STATION

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**Insect control pays dividends when good cotton is grown on good land.
Yield of seed cotton was more than doubled in dusted plot at the right.**
(Photo courtesy U. S. Bureau of Entomology and Plant Quarantine.)

Summary of Recommendations

For Insect Control

1. Be prepared well in advance of the cotton growing season to combat insect infestations. Select a dusting machine of the right type for your acreage. Purchase your insecticides early and store in a dry, protected place. Under present war conditions you cannot afford to wait before ordering these necessary supplies.

2. If you live in eastern Oklahoma, the boll weevil will be your most serious insect problem. Watch your fields closely, particularly after the plants start to set their first squares, and start your dusting program when 10 percent are infested by this insect.

3. Any lack of proper fruiting may be due to the fleahopper. This is especially true if your field is near overgrazed pastures or where there is a heavy growth of croton weeds. If fleahoppers are at work, it may be profitable to control them by dusting with superfine conditioned dusting sulphur. However, remember, especially if you live in southwestern Oklahoma, that hot, dry weather may cause excessive shedding, thereby offsetting the beneficial results of the dusting.

4. Watch for leaf aphid infestation, especially if you have dusted your fields several times with calcium arsenate to control boll weevil. If leaf aphid develops, dust with a 3 percent nicotine dust.

5. Don't guess. Treat your field only when you know by actual plant examinations that insects are present in injurious numbers.

6. Dust your fields only when the proper air conditions prevail. This means calm or nearly calm air. Cease dusting as soon as it becomes windy, even though you have not completed the job.

7. Plant as early as is consistent with good farm practice, because early cotton has a better chance to produce a crop if boll weevil infestation is heavy.

8. Plant a variety that is adapted to your local conditions, and that produces good staple.

For Plant Disease Control

9. Large spots of dead cotton plants in the southern counties indicate Texas root rot, which cannot be completely eradicated but may be reduced to a minimum by a four-year rotation of cotton with crops of the grain and grass family.

10. Scattered dead cotton plants in eastern Oklahoma are usually caused by wilt, a disease that is controlled by use of wilt-resistant varieties and the application of potash-containing fertilizer.

11. Bacterial blight causes angular leaf spots and boll spots, devitalizing plants and reducing yields. It is controlled by seed treatment and a 2-year rotation of cotton with any other crop.

12. Seedling blight produces poor stands, especially in wet, cold seasons, and later results in boll rot. It is minimized by seed treatment.

13. Seed dusting insures against seedling blight and pays good returns in Oklahoma, at a material cost of 4-6 cents per acre.

14. Gin-delinted or reginned seed produces somewhat better stands and yields than untreated seed, and when dusted, is second in quality only to acid-delinted and dusted seed.

15. Acid delinting of seed, followed by grading and seed dusting, gives the highest quality planting seed available, although on the farm the operation is more difficult than dusting. Acid-delinted, graded, and dusted seed is commercially available in Oklahoma.

KEY

for Determining Cause of Damage

A. Principal symptoms in seedling stage.	
1. Poor stands with seedlings failing to emerge or withering and dying soon after emergence.	
Seedling blight	28
2. Large seedlings with many angular dead spots on leaves; sometimes death of the seedling.	
Bacterial blight	27
B. Principal symptoms in mature plants.	
1. Plants suddenly dying in midsummer	
a. In southern counties only; dead plants in large patches in the field; roots decayed.	
Texas root rot	24
b. In acid soils of eastern Oklahoma principally; dead plants scattered through the field; roots not decayed; wood under bark brown and wet.	
Wilt	26
2. Plants injured but not dying	
a. Leaves with many small, angular dead spots.	
Bacterial blight	27
b. Leaves rusty red or brown.	
"Rust"	26
c. Leaves dropping from plant, leaves and fruit coated with clear sticky deposit on which a sooty mold grows, numerous greenish plant lice on lower leaf surfaces.	
Cotton leaf aphid	15
d. Plant defoliated by greenish to blackish caterpillars.	
Cotton leafworm (See Fig. 10)	19
3. Plants not fruiting normally	
a. Very small squares blasted, plants show excessive vegetative growth, sometimes growing tall and whiplike.	
Cotton fleahopper (See Figs. 6 and 7)	16
b. Few blooms, and many squares shed, squares yellowed with bracts "flared," punctures and "stings" present together with orange-yellow granular material on some.	
Boll weevil (see Fig. 2)	6
c. Bolls show numerous "stings" and punctures, frequently 1 or more locks undeveloped, opened bolls show much diseased lint.	
Boll weevil (see Fig. 3)	6
d. Bolls and squares attacked by large greenish or brownish worms which cut into them and hollow out interior.	
Corn earworm or bollworm	21
e. Moldy spots on bolls, lint discolored or decayed, bolls often fail to open.	
Boll rots	28
f. Round, water-soaked, then brown spots on bolls; sometimes moldy in later stages.	
Bacterial blight	27

CONTENTS

SUMMARY OF RECOMMENDATIONS	2
KEY FOR DETERMINING CAUSE OF DAMAGE	4
INTRODUCTION	6

COTTON INSECTS

The boll weevil	6
How the weevil cuts the yield	6
Biology of the weevil	7
How to determine when to poison	12
Count of infested squares shows danger point	12
Poisoning not economical on unproductive soils	13
Calcium arsenate dust controls the weevil	13
Mopping method of weevil control is not effective	14
Beware of nostrums	15
The cotton leaf aphid	15
The cotton fleahopper	16
Prevention	18
Control	18
The cotton leafworm ("Army worm")	19
The cotton bollworm	21

SELECTING A DUSTER

Hand gun	21
Saddle gun	21
Traction duster	22
Tractor-operated duster	22
Power-operated duster	22
Combination cultivator-duster	23
Airplane dusting	23

COTTON DISEASES

Root rot	24
Chiefly affects southern counties	24
Crop rotation prevents serious losses	25
Wilt	26
Most common in east-central Oklahoma	26
Resistant varieties and potash fertilizer give control	26
Bacterial blight	27
Oklahoma's most prevalent cotton disease	27
Seed treatments and crop rotation reduce losses	28
Seedling blight and boll rots cut production	28

SEED TREATMENTS FOR BLIGHTS AND BOLL ROT

Value of seed treatments	29
How to dust cotton seed	30
Acid delinted seed	31

Protecting Cotton From Insects and Plant Diseases

By F. A. FENTON and K. STARR CHESTER*

INTRODUCTION

Insects and plant diseases each year take a toll of Oklahoma's cotton crop. Most of this loss can be prevented by timely and correct control or preventive measures. Only the most serious diseases and insects are considered in this bulletin, together with tested and approved methods of checking or eliminating them. A means of quickly and easily identifying the insect or disease which is causing damage is provided in the illustrations and in the field identification key on page 4.

COTTON INSECTS

THE BOLL WEEVIL**

In Oklahoma, the cotton boll weevil is most serious in the southeastern counties (Fig. 1). In those counties, the winters are mild, there is an abundance of woodlands for protective cover during the winter, and usually there are frequent rains during the growing season. To the north and west the infestation on the average becomes progressively lighter because of lower winter temperatures, lower summer rainfall, or both. Occasionally the insect causes severe losses over a considerable portion of the cotton area of the state whenever climatic conditions in these parts approach those favorable for the weevil. In the extreme southwestern part of Oklahoma (Kiowa and Tillman counties and westward), the insect is rarely seen and is of no economic importance whatever.

HOW THE WEEVIL CUTS THE YIELD

Most severe injury is caused by the development of the immature stages of the weevil in cotton squares. For most varieties of cotton, the square sheds from the plant within 6 or 7 days after the egg has been laid. Thus, severe weevil infestation effectively stops cotton from blooming, and the plants fail to set a crop of bolls.

* Department of Entomology, and Department of Plant Pathology, respectively. Photographs not otherwise credited are by G. A. Bieberdorf and Ephriam Hixson, Department of Entomology.

** *Anthonomus grandis* Boh.

When squares become scarce, the weevils begin puncturing small bolls; and later, when small bolls are no longer available, they begin puncturing larger ones. Small bolls are shed from the plant the same as squares. Older bolls remain attached to the plant, but from one to all locks of cotton may be destroyed by the weevils.

As the cotton bolls become older, a thin membrane develops between the hull of the boll and the developing lint within. When this membrane hardens, it makes an effective

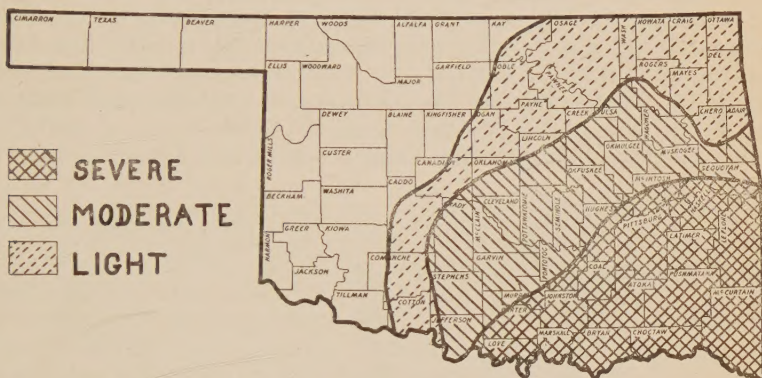


Figure 1. Zones of boll weevil infestation in Oklahoma. In some years, the zone of severe infestation extends considerably north and west of the line shown on this map.

barrier through which the weevil cannot penetrate. This point is reached in from 20 to 30 days after blooming, depending upon variety and season.

In heavily infested fields the plants may produce a bottom crop of bolls, but the middle crop is severely damaged or destroyed, and no top crop is produced.

BIOLOGY OF THE WEEVIL

Boll weevils (Fig. 2) pass the winter in various protected situations which are chosen by the insects more or less at random as they leave the cotton fields in the fall following the first killing frost. The weevil is very susceptible to freezes so a majority succumb during the winter, chiefly in exposed situations or in the northern and western parts of the state. Studies made at Henryetta by the Department of Entomology of the Oklahoma Agricultural Experiment Station show that

when the lowest winter temperature was 12 degrees F. there were 410 weevils per acre in the cotton in the early summer as compared with 80 when the lowest temperature was 2 degrees and 30 when it was 5 degrees below zero. These records show the insect is very greatly checked by severe cold spells during the winter but that a few survive despite the severest of freezes. Extensive cage tests in Oklahoma and other states show that on the average a very small percentage of weevils survive the winter even under fairly favorable conditions.

The movement of the weevils from winter quarters to cotton fields is usually a gradual process, beginning early when the plants are small and continuing for a while after the first squares are formed. During the early movement into the cotton fields, the weevils feed on the tender, growing leaf buds at the tip of the plant or they may cut into the leaf petioles. Fields located near wooded areas or bordered by dense woods



Figure 2. Enlarged view of boll weevil.

are infested first, and usually most of the weevils will be found in those portions of the field nearest the woods. As soon as the plants start to produce squares, the weevils attack these. They feed by chewing a small hole in the square and eating the tender, developing anthers within. At this time infested squares may show several feeding punctures and the presence of a yellowish material which is the excreta of the insect. Such infested squares are usually shed by the plant within a week after being punctured by the weevil.

The overwintered weevils live for a month or more and continue to lay eggs during this time. When the egg is laid, it is forced in and among the anthers through a hole chewed by the weevil for this purpose. This hole is then sealed by the female and appears as a small speck or "sting" on the side of the square (Fig. 3). As the square grows, this speck frequently protrudes, giving a wartlike appearance. More than one egg is seldom laid in a square, and one weevil may lay eggs in as many as 30 squares in a day.

The egg soon hatches into a grub which starts at once to feed on the anthers. This causes the square to turn a yellowish green, the bracts open up or "flare," and within 6 to 7 days after the egg has been laid the square drops from the plant. (In a small percentage of cases it remains partly attached to the plant but becomes dry and hard.)

After the square has dropped to the ground, the weevil grub continues to feed (Fig. 4) and soon leaves nothing but an empty shell within which it changes into the delicate white resting stage or pupa, (Fig. 5) from which in due time the weevil emerges by cutting its way out through a round hole in the side of the square. During the week or more that the weevil grub and pupa are imprisoned in the square, they are very susceptible to high surface soil temperatures and in prolonged dry, sunny periods are killed. This is the principal reason why hot dry weather checks weevil development.

First generation weevils begin to appear in any cotton field at about the time the first blooms open. They can be readily distinguished from the overwintered weevils, which are gray, by their reddish-brown appearance. These first generation weevils soon start egg deposition and in a short time their numbers greatly augment those of the overwintered weevils, thereby rapidly increasing the infestation.

There are two complete and a partial third and fourth generations a year. Usually the fourth generation consists only

of a few individuals which develop in the late squares. The reason for this apparently limited number of generations is the slowing up of weevil development as soon as the plants stop fruiting. Whereas the weevil develops in as short a time as



Fig. 3. Cotton square showing typical weevil puncture; frequently the egg puncture appears as a small speck, only slightly larger than those normally present on the square.

16 to 18 days in a square; in bolls the period is greatly prolonged to 30 days or more. Moreover, when forced to feed on and lay eggs in bolls, the weevils' reproductive powers are greatly reduced.

Under favorable conditions a few weevils in a cotton field in the spring mean tens of thousands by fall. Therefore, where this insect is a problem, the production of a cotton crop is a race between the cotton plant and the weevil. Late planted cotton is severely handicapped and there is much less likelihood of a profitable crop being produced than when it is planted early.



Fig. 4. Fully developed weevil grub in cotton square.

HOW TO DETERMINE WHEN TO POISON

Count of Infested Squares Shows Danger Point.—Careful studies have shown that the weevil causes damage only when it is sufficiently numerous to increase the shedding of the cotton plant over and above that which normally occurs. The danger point is reached when the insect is infesting an average of 10 percent of the squares early in the season. If this point is reached or approached, the field should be dusted at once with calcium arsenate.

The most accurate method to determine when 10 percent of the squares are infested is to collect 100 squares at each of five locations in the field, one near each corner and one in the center. A more rapid and equally satisfactory method is to



Fig. 5. Weevil pupa in cotton square.

pick the squares at random while walking diagonally across the field. A cursory examination of the field and noting an unusual number of shed squares on the ground may or may not mean a weevil infestation, since the shedding of squares in excessive numbers may be caused by other agencies.

It is sometimes desirable to put on an early season application of poison to check overwintered weevils; but, unless hot weather controls the insects, later applications are also necessary. This is due in part to the migratory tendencies of the weevil. In years of severe infestation the weevils fly from field to field, thus spreading the infestation to fields hitherto lightly infested.

Poisoning Not Economical on Unproductive Soils.—It is well to remember also that controlling the boll weevil will not make cotton, but only protects what the plant and soil are capable of producing. Therefore, poison is only recommended on the richer, heavier producing soils where at least $\frac{1}{3}$ bale per acre is possible, and when the weevil infestation is sufficiently heavy to warrant control measures. In general a price of at least 10 cents per pound for lint should be expected to make poisoning cotton profitable even with a heavy weevil infestation. Experiments by entomologists at the Oklahoma Station from 1928 to and including 1933, in which 48 plats were dusted, showed that an average of seven or eight applications is needed to obtain control. These experiments also showed that the average gain in yield of the dusted plats over the check was 348 pounds of seed-cotton per acre at a cost of \$1.25 for each 100 pounds of gain of cotton in the field, or unpicked. This included a year when the boll weevil infestation was very light and the average gain was only 129 pounds, and also a year when the infestation was very heavy and the average gain was 569 pounds. These tests were made in fields selected especially because of their heavy weevil infestation.

CALCIUM ARSENATE DUST CONTROLS THE WEEVIL

The recommended insecticide to combat the boll weevil is full strength calcium arsenate (not diluted with hydrated lime), applied as a dust. It is highly toxic to the insect, non-injurious to the plant, and comparatively cheap. Experiments have shown that the weevil consumes a lethal dose by picking up the tiny bits of poison accidentally on the tip of its proboscis. Four pounds per acre on the average are sufficient for early or presquare applications on young cotton. Older and larger plants need 5 to 6 or 7 pounds per acre per application.

As soon as inspection reveals 10 percent of the squares infested, the first application of calcium arsenate should be made at the earliest favorable opportunity which is during a period of calm or nearly calm air. It is useless to dust when there is sufficient breeze to blow the dust cloud out of the field. The air condition must be sufficiently quiet to allow the dust cloud to settle evenly over all parts of the plants.

The first dust application must be followed by two more at five-day intervals to check the weevils. One application will not do this, as there are usually weevils emerging from infested squares every day and these will continue to cause injury. They are not killed by the first application, which remains effective for only a day or so. Should a rain occur within 24 hours after an application the field should be dusted again as not enough weevils will receive a lethal dose unless the calcium arsenate remains on the plants for at least 24 hours.

Subsequent applications may be needed if and when the infestation increases again to dangerous proportions. In some parts of the country, notably in the eastern cotton producing states, excessive applications of calcium arsenate to cotton cause certain soil conditions to develop which are unfavorable for growing crops following the cotton. So far as known this condition has not been observed in Oklahoma.

MOPPING METHOD OF WEEVIL CONTROL NOT EFFECTIVE

The application of poisoned sweet bait mixture to the tops of the cotton plants for combating the boll weevil has been thoroughly tested in Oklahoma by Federal and Oklahoma Station entomologists and failed to give adequate control. The formula consisted of one pound of calcium arsenate, one gallon of water and one gallon of molasses. It was applied to the growing tips and terminal buds by a home-made mop within 24 hours after being mixed. On young cotton, about one gallon of the mixture was used per acre.

This method was compared with the calcium arsenate dust treatment in several combinations such as weekly applications of the molasses mixture versus dusting, early applications of the molasses mixture versus dusting, the value of one presquare application of the molasses mixture in cutting down later dust applications, and the effect of frequency of applications of the molasses mixture on control. These experiments proved conclusively that the molasses mixture when used alone did not control the boll weevil.

BEWARE OF NOSTRUMS

Probably no other insect has had so many compounds and devices invented for control. Some of these were honestly believed by their inventor to control the boll weevil. Others, were definitely developed to take money away from the cotton farmer. Included in this long list are sprays, seed treatments, weevil collecting machines, and countless others. Until these methods are based on sound principles of insect control and have been tested and shown effective, they cannot be recommended.

THE COTTON LEAF APHIS*

In some states, excessive dusting of cotton with calcium arsenate to control the boll weevil causes heavy leaf aphid infestations to develop. These insects have piercing-sucking mouth parts and are not killed by the calcium arsenate, which is a stomach poison. A heavy leaf aphid infestation may cause excessive leaf shedding and the production of "honey dew," a clear, sticky liquid which is likely further to increase damage to the crop. Only two instances of such damage occurring in Oklahoma have come to the attention of entomologists at the Oklahoma A. and M. College; but the cotton farmer who intends to dust his cotton with calcium arsenate needs to keep the possibility of leaf aphid damage in mind and be prepared to combat it if necessary.

The best method to control leaf aphid is to dust the plants with a 3 percent nicotine dust at the rate of 8 to 14 pounds per acre. This may be applied by the same dust machine as used for the calcium arsenate and it is even more important to do the nicotine dusting in absolutely calm air. This is because the nicotine in the dust mixture is released as a gas and is rapidly diffused in the air. To obtain control the gas must remain around the plants for a few moments to suffocate the aphid. Applying nicotine dust with a cloth trailer attached so as to help retain the dust over the plants, while successful on certain truck crops, has not given uniform success in cotton dusting. Much better results will be obtained by dusting in absolutely calm air. Nicotine dust also should not be applied unless the air temperature is at least 70 degrees F.

* *Aphis gossypii* Glov.

THE COTTON FLEAHOPPER*

If cotton is not setting a normal crop of squares and weather cannot be charged with this condition there is a possibility that the cotton fleahopper is responsible. This insect blasts the tiny squares shortly after they first appear by puncturing them with its sucking mouthparts. Such blasted squares can be easily found by careful search, or the scars where they were developed can be seen on the fruiting branches. Heavily infested plants fail to set a normal crop of fruit (Fig. 6) and may grow tall and whiplike (Fig. 7). The fleahopper is a very



Figs. 6 and 7. Plants injured by the cotton fleahopper.

(Courtesy Texas Agricultural Experiment Station.)

small insect, not being much over $1/32$ inch long when just hatched to $1/8$ inch when full grown. These tiny, pale-green insects can be located by carefully examining the terminal buds. The adults are winged and will be flushed from the plants when disturbed.

The cotton fleahopper inserts its eggs in great numbers in the pithy stalks of many kinds of weeds, especially the crotons (Fig. 8). The insect overwinters in the egg stage in weedy fields. Overgrazed pastures are favorite places where these croton weeds grow. Sometimes these plants grow so abundantly that they are the dominant or most common weed growing in these overgrazed pastures (Fig. 9). In the spring a generation of fleahoppers is developed on these weeds, some-

* *Psallus seriatus* Reut.



Fig. 8. A croton weed, one of the many weeds on which the fleahopper develops and in the stems of which it lays its eggs.

times in enormous numbers. When the crotons dry up, or mature, the fleahoppers are forced to migrate to cotton; and fields hitherto but lightly infested are soon invaded by swarms of these insects which at once start attacking the small squares. In southwestern Oklahoma this flight from the crotons to cotton takes place in July and from this month to the end of the growing season cotton fields may remain infested. In eastern Oklahoma, the cotton fields may become infested earlier and the insect may later leave, thereby enabling the plants to set a late crop of bolls. This late crop, however, is subject to attack by the boll weevil, which does its heaviest damage late in the season; and it is therefore better to control a fleahopper infestation than to depend on getting a late crop after the fleahoppers have left.

PREVENTION

The permanent solution of this problem, at least in southwestern Oklahoma, is pasture improvement. Overgrazed pastures, abandoned farms, farm lots where crotons are allowed to grow, are all potential sources from which these insects come. Overgrazing is perhaps the most serious agricultural malpractice favoring fleahopper development. Improvement of pastures by removing the livestock and mowing the weeds and sage will eventually allow grasses to return and eliminate much of the croton growth.

CONTROL

Experiments to date at the Southwestern Cotton Substation at Tipton show that dusting cotton with superfine dusting sulphur resulted in an average increase in yield of 91 pounds of seed cotton per acre for a four-year-period. In two of these years increases of 147 and 219 pounds of seed cotton per acre were obtained; but in two other years, one when fleahoppers were unusually destructive, no significant gains were made. These plats were dusted twice with sulphur at the rate of 15 pounds per acre per application.



Fig. 9. Effect of overgrazing on growth of croton weeds, which are shown growing luxuriantly inside the fence. It is in such areas that the cotton fleahopper develops.

The cotton farmer should, therefore, remember that flea-hopper control by dusting with sulphur under southwestern Oklahoma conditions at least, is in the nature of crop insurance. It may pay big dividends and then again it may not. In eastern Oklahoma, where cotton shedding because of hot dry weather occurs less frequently, the chances of increasing yields by sulphur dusting are much greater.

The sulphur used should be purchased as superfine conditioned dusting sulphur, from 93 to 95 percent or more of which should pass through a 325-mesh screen. Applications should begin when 20 fleahoppers are found per 100 terminals or when fruiting conditions and careful plant examinations show these insects to be present in damaging numbers. When small blackened, dead squares less than a quarter inch in size are numerous, it is a sign that these insects are seriously checking plant fruiting.

THE COTTON LEAFWORM*

The leafworm, or "army worm" as it is sometimes erroneously called, frequently strips the leaves from cotton plants. It appears in southern Oklahoma in late August and reaches the northern cotton growing areas of the state in September or October. The caterpillars and their work are familiar to every cotton farmer (Fig. 10). The insect is unable to survive Oklahoma winters and cotton fields are reinfested each year by moths migrating into the state from the South. Infestations of continental United States by this insect start each year from moths migrating from the West Indies. In years when cotton is late and the infestation comes early, severe damage is caused by the insect because it strips the leaves from the plants before the bolls have matured. Heavy infestations developing when much cotton is open may also cause staining of the lint following rains. Under certain conditions when the crop is "made," and many bolls are mature but not open, stripping the plants of their leaves by the leafworm is beneficial because it allows the sun to penetrate to the bolls and causes them to open earlier. This checks boll rots. Furthermore, heavy leafworm infestation stops cotton from fruiting; and, in areas where the boll weevil is a problem, this tends to starve the weevil so that it is less able to survive the following winter.

* *Alabama argillacea* Hbn.

Dusting cotton with undiluted calcium arsenate effectively controls the leafworm. Best results are obtained by applications when the caterpillars are small. These insects develop very rapidly and even a short delay in dusting the field may mean severe injury.



Fig. 10. Cotton Leafworms ("Army worms").

THE COTTON BOLLWORM*

The cotton bollworm may seriously reduce yields by destroying bolls. The large caterpillars are the same species as the familiar corn earworm. They bore into the green bolls and may completely hollow them out. Squares and blooms are also attacked. This insect is very difficult to control but best results are obtained by dusting with calcium arsenate at the rate of 10 pounds per acre and being sure that the nozzles of the dusting machines are practically touching each row of cotton treated. Several applications at five-day intervals may be needed.

SELECTING A DUSTER

Dusting machinery gives better protection by more even distribution of the dust and uses less dust per acre than crude hand methods such as the old bag-and-pole method. Machines which are driven along the border of a field and blow the dust across many rows are not recommended. Tests have shown that the first few rows are protected, but beyond this there is little or no insect control.

HAND GUN

The hand gun is the smallest type of duster which can be recommended, and then only for small fields of not over eight acres. It is carried in front of the operator, being held in place by straps, and should have one nozzle for dusting one row at a time. (Fig. 11.) Hand guns provided with two nozzles to dust two rows are not recommended.



SADDLE GUN

The saddle gun (Fig. 12) is also operated by hand and is carried on horseback when used. The operator sits astride the animal and cranks the gun as the horse is driven between the rows at a slow pace. These machines have an outlet extending down on either side of the animal so that two rows of cotton may be dusted at the same time. A saddle gun will care for the dusting of 30 acres of cotton a season. It is adapted for use in stumpy fields where a horse or mule drawn implement could not go, and also can be used in muddy fields.

* *Heliothis armigera* Hbn.



Fig. 11. Hand guns in operation.

(Courtesy U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.)

TRACTION DUSTER

Traction dusters develop power from one or both wheels as they are drawn across a field. They must be geared sufficiently high so that they can be pulled at a moderate speed and still develop plenty of air blast. There are numerous makes and types. They will dust from two to four or more rows. Smaller types will care for 30 to 50 acres of cotton a season and larger ones 70 to 140 acres.

TRACTOR-OPERATED DUSTER

Some dusters are made to be pulled by a tractor and use a power take-off device to operate the blower. Where tractors are available and the cotton fields large, these machines are for the most part very satisfactory (Fig. 13).

POWER-OPERATED DUSTER

Power-operated dusters, although more costly than other types, are very satisfactory as they will generate sufficient air blast to cover thoroughly all parts of the cotton plant without being driven at an excessive rate of speed through the fields. There are many types available, with attachments for dusting six to eight or more rows of cotton at a trip. They will care for dusting 200 to 300 acres in a season.

COMBINATION CULTIVATOR-DUSTER

The cultivator duster is equipped so that it can be attached to horse-drawn cultivators so that dusting and cultivation can be done at the same time. These machines can be used only in young cotton. When cultivating operations cease and the plants are larger, these machines can no longer be used. In most localities in Oklahoma, air conditions are not suitable for dusting during the day, when cultivation is done.

AIRPLANE DUSTING

Custom dusting of cotton by airplane dusting companies is now done in many localities where large acreages of cotton are located in single communities. The price charged per acre may include the cost of the dust and all other charges, or the farmer may supply all calcium arsenate. The chief advantage of airplane dusting is the speed with which large fields can be treated—of vital importance in many instances where climatic conditions have prevented adequate protection by ground machinery. Planes are not restricted by muddy cotton fields, and can also operate in the day at times when



Fig. 12. Saddle gun for dusting cotton.

(Courtesy Arkansas Agricultural Experiment Station.)



Fig. 13. Tractor-operated duster.

(Courtesy John Deere.)

moderate air currents make dusting with ground machines inadvisable. A duster-plane can dust 350 or more acres of cotton per hour.

COTTON DISEASES

Cotton is affected by several important contagious diseases that each year cause losses of thousands of bales in the Oklahoma crop. Two of these diseases, Texas root rot and wilt, kill the maturing plants outright; a third, angular leaf spot or bacterial blight, saps the vitality of the plants throughout life and often results in rotting of the bolls; and a fourth, seedling blight, results in poor stands and later spreads to the bolls, destroying them with a moldy decay. Destructive as these diseases are, the damage done by each can be reduced by control practices.

ROOT ROT

CHIEFLY AFFECTS SOUTHERN COUNTIES

Cotton growers in the southernmost two tiers of counties in Oklahoma are familiar with the large patches of dead plants that appear in many fields from July onward. These patches of dead cotton, from a few square yards to an acre or more in size, are often called "alkali spots"; but in the majority of cases where the cotton reaches blossoming stage in a healthy condition and then suddenly dies, the disease is root rot,

caused by a fungus* that lives in the soil. This fungus is capable of destroying many kinds of crops besides cotton, including alfalfa and other field legumes, many vegetable crops, and fruit and shade trees. The grain crops are not affected by the root rot fungus, nor are certain species of trees and ornamental plants.** Winter legumes and early vegetable crops although susceptible to root rot, may be grown successfully on infested soil, since the disease is active only in the hot weather.

Root rot is recognized and distinguished from wilt and other cotton diseases by the occurrence of dead plants in spots in the field during midsummer. In Oklahoma it is limited to the Red River and adjacent counties and is most prevalent in heavy, neutral or basic soils. Affected plants die suddenly, after a day or two of wilting, and the root systems are so decayed that such plants easily slip out of the soil. The rotted tap root is covered with fine, brownish fungous strands, by which the disease is positively identified. The spots appear in about the same location in the field from year to year, although they may slowly enlarge, or sometimes will almost disappear for a season, only to reappear the following year.

CROP ROTATION PREVENTS SERIOUS LOSSES

Once the root rot fungus is in the soil it is impractical to attempt to eradicate it. It will persist for many years, even in the absence of susceptible crops. The grower with an infested acreage must learn to live with the disease and adapt his cropping system so as to reduce the damage to a low level. This is done by adopting a system of crop rotation in which cotton is grown on the same infested land not oftener than once in four years. In the three intervening years the land should be used for a non-susceptible crop, such as wheat, oats, barley, sorghum, corn, or Sudan grass, or for a winter legume crop followed by bare summer fallow. Susceptible perennial crops such as alfalfa, perennial clovers, or fruit trees will invariably fail on infested soil. As the fungus spreads only by growing from plant to plant in the soil, a small root rot spot may be isolated from nearby, non-infested fields, by maintaining a barrier of bare fallow or some non-susceptible crop, such as several rows of corn or sorghum.

* *Phymatotrichum omnivorum* (Shear) Duggar

** A detailed list of these will be found in Oklahoma Agricultural Experiment Station Mimeographed Circular 53, which is available on request.

WILT

MOST COMMON IN EAST-CENTRAL OKLAHOMA

Another killing disease of cotton, wilt, is commonly seen in the area from Tulsa and Muskogee southward to Hughes county and McAlester, and less frequently on acid soils in other parts of the state. Like root rot, wilt kills plants from mid-season onward, and fields have been found in Oklahoma in which every plant had been killed by wilt by picking time, resulting in greatly reduced yields of poor quality fiber and a high percentage of unopened bolls. In wilt, unlike root rot, affected plants are usually scattered through the field, rather than in well marked spots, and the root system of wilt-killed plants is not decayed. Wilt is also characterized by a brown, moist discoloration of the wood, easily recognized when the bark of stem, tap root, or main branches is peeled back.

The type of wilt commonly occurring in Oklahoma is caused by a fungus* that lives in the soil for long periods of time. It attacks only cotton and okra. Wilt diseases of other crops such as watermelons, tomatoes, sweet potatoes, and flax are caused by other fungi that will not attack cotton; hence the presence of the cotton wilt fungus in the soil will not interfere with the successful cultivation of other crops in infested soil. The wilt fungus is largely restricted to acid soils that are deficient in potash, so that it rarely if ever occurs in the same field with root rot. The fungus is spread from one part of the field to another by microscopic, wind-borne, seed-like spores. It is rarely introduced into new locations with infested cotton seed.

RESISTANT VARIETIES AND POTASH FERTILIZER GIVE CONTROL

Plant breeders have succeeded in developing several cotton varieties that are wilt-resistant and can be grown successfully on wilt-infested soil. Plant pathologists at the Oklahoma station have found Stoneville 2-B and Roldo Rowden to be wilt-resistant. These varieties are high yielding and are well suited to Oklahoma. The use of wilt-resistant varieties together with an application of potash-containing fertilizer will solve the wilt problem under Oklahoma conditions. The amount and type of fertilizer to use depends on local soil conditions. Deficiency of potash in cotton soils by itself often causes a rusty-brown spotting of cotton leaves, sometimes called "rust."

* *Fusarium vasinfectum* Atk.

and in general the amount of potash fertilizer to use is the minimum required to eliminate this rusty condition.

While nearly all cotton wilt in Oklahoma is prevented by these practices, there is a second wilt disease of cotton* which has rarely been found in the state. Its effects are similar to those of the common wilt, but it is not controlled by the use of resistant varieties and potash fertilization. For this reason, growers with a serious wilt problem are advised to send a few affected stems to the Plant Pathology Department of the Agricultural Experiment Station at Stillwater for laboratory diagnosis before undertaking a wilt-control program.

BACTERIAL BLIGHT

OKLAHOMA'S MOST PREVALENT COTTON DISEASE

In all parts of Oklahoma where cotton is grown, bacterial blight (angular leaf spot; bacterial boll rot; black arm) is a problem. It does not kill plants ordinarily; but it devitalizes them by destroying the leaf tissues and predisposes the bolls to rot. In extreme cases, young plants, less than a foot high, may be so badly blighted that they die or never develop into normal maturity.

Bacterial blight is recognized by the presence of numerous, small, angular-shaped spots on the leaves. These spots first appear watersoaked, then dry out and become brown or black. When the spots are abundant the leaves may wither and fall. Blight spots on seedling-leaves or bolls are round instead of angular-shaped. They, too, appear watersoaked at first, and then dead. Occasionally stems are affected, with long black patches that may girdle the stem and kill the plant.

By itself, the blight germs do not rot the bolls, but they make openings in the bolls through which mold fungi can enter and discolor or rot the lint, with the result that many rotted bolls will be found in blight-infested fields.

Blight is caused by bacteria or germs** that for the most part are carried from one crop to the next in the fuzz of cotton seed. To a limited extent they can overwinter in the soil. They are spread from plant to plant by wind-driven rain or surface water. Cotton is the only plant which they can attack, but all cotton varieties commonly grown are susceptible to the disease.

* *Verticillium* wilt.

** *Phytophthora malvacearum* (E. F. S.) S. A. B.

SEED TREATMENTS AND CROP ROTATION REDUCE LOSSES

While blight cannot readily be eliminated, its most destructive effects can be prevented by seed treatments combined with a crop rotation program in which cotton is grown on the same land in alternate years with any other crop. If seed from uninfested cotton fields is available seed treatment will not be a necessary feature of blight control. The two leading types of seed treatment, dusting and acid delinting, are described on pages 30 and 31.

SEEDLING BLIGHT AND BOLL ROTS CUT PRODUCTION

Every cotton grower has had the experience of seeing planting followed by poor stands in which many seedlings fail to break through the soil, or wither and die in an early stage. Such failures are most common in cold, wet seasons, and are usually attributed to the weather. Actually they are often caused by fungus parasites in the soil or on the seed. The attacks of these parasites on young seedlings are favored by the cold, wet soil. The weather cannot be controlled, but the injury caused by these seedling-blight fungi can largely be prevented by suitable seed treatment.

Later in the development of the cotton plant, the seedling blight fungi are carried by the wind to the bolls where they enter and by feeding on the lint discolor or rot it. Prevention of seedling blight by seed treatment goes a long way in reducing boll rot later on.

SEED TREATMENTS FOR BLIGHTS AND BOLL ROT

VALUE OF SEED TREATMENTS

The germs and fungi that cause bacterial blight, seedling blight, and boll rots live from one crop to the next either on the fuzz of cotton seed or in the soil (and, to a slight extent only, within the seed). Seed treatment with a chemical dust has two purposes: (1) to kill the germs of disease on the seed surfaces, and (2) to surround the seed with a chemical vapor that poisons or repels attacking blight organisms in the soil. Seed treatment with concentrated sulphuric acid kills germs and fungi on the seed surface, removes the fuzz which aids grading to remove light, immature or internally diseased seed, and greatly hastens germination, which minimizes seedling blight by shortening the germination and seedling period

in which the cotton plant is susceptible to attack by blight fungi. The combined advantages of both treatments may be secured by dusting seed after it has been acid-delinted.*

Cotton seed may also be partially delinted by reginning. During the national emergency the linters obtained by reginning cotton seed are in great demand for the manufacture of munitions. At the present time it is mandatory that all cotton seed to be used for crushing be first reginned, and while this order has not yet extended to seed to be used for planting purposes, that step may follow. In any case, growers will probably find reginned seed readily available in most communities. Although the experiments with reginned seed which have been conducted by plant pathologists at the Oklahoma station have been carried out only over a limited period of time, the results agree with those of other states in showing that reginning benefits the seed for planting purposes, giving a type of seed intermediate in quality between untreated and acid-delinted seed. Gin-delinted seed germinate somewhat sooner than ordinary seed and usually produce somewhat better stands and yields, although not quite as good as those from acid-delinted seed. Reginning does not destroy disease germs on the seed nor protect it from blight in the soil; however, reginned seed may be more easily dusted with chemical dusts than ordinary seed, and when this is done will prove to be a significant improvement over ordinary untreated seed.

Seed treatment is not a cure-all for cotton troubles. It will not bring dead seed to life; and under extremely adverse weather conditions even treated seed will succumb, while if the weather is highly favorable for seedling development, untreated seed may do as well as treated seed. However, tests by the Plant Pathology Department of the Oklahoma Agricultural Experiment Station over the past five years have given abundant proof that under average conditions seed treatments give quicker germination, better stands, stronger plants, and increased yields. The cost of the treatments is small, a few cents per acre that is many times repaid in improved production. Cotton seed treatment may be looked upon as a low-cost form of insurance that minimizes the hazards of getting a stand under unfavorable weather conditions, and in addition adds to the yield by reduction of losses from bacterial and seedling blight and boll rot.

* There is a method of delinting cotton seed with hydrochloric acid gas, but this has not been tested at the Oklahoma Experiment Station, and accordingly no recommendations on gas-delinted seed can be made at this time. Seed treatment with growth hormones for increasing vigor and productivity of cotton is under study at the Experiment Station, but this type of treatment is not concerned with disease-control, and is not considered in this bulletin.

Of the two treatments, seed dusting and acid delinting, the dusting is much easier to carry out on the farm and for this reason is the preferred method with most growers. Indeed, in the few years since seed-dusting has been developed, some of the cotton states have reached the point where 95 percent or more of the state acreage is planted with dusted seed. In Oklahoma the adoption of seed dusting has been so rapid that while three years ago not more than 5 percent of planted seed had been treated, persons who are in close touch with the cotton industry in Oklahoma report that in 1942 from 75 to 90 percent of the cotton seed planted in Oklahoma is being treated. Nearly all workers agree that acid delinting, followed by grading and seed dusting, gives the highest quality planting seed available; but on the farm the acid treatment is rarely used because it is slow, it involves the disagreeable and somewhat dangerous handling of concentrated acid, and it creates a problem in disposal of the acid waste.

HOW TO DUST COTTON SEED

The chemicals in universal use for cotton seed dusting are two organic mercury compounds sold under the trade names of "New Improved Ceresan" and "2% Ceresan" respectively. The dust is used at the rate of $1\frac{1}{2}$ oz. ("New Improved Ceresan") or 3 oz. ("2% Ceresan") per bushel of cotton seed at a cost for chemical used of 4 to 6 cents per bushel treated. On the farm, the dust can be applied with a homemade revolving barrel seed duster, which is also useful for treating grain seed and for inoculating seed of legumes. Directions for making and using such a treater can be obtained by writing to the Plant Pathology Department of the Oklahoma Agricultural Experiment Station at Stillwater. Dusted seed does not deteriorate and may be treated at any time between crops or may even be stored for use the second year after harvest. The seed should be treated, however, at least 24 hours before planting. **DUSTED SEED IS POISONOUS** to farm animals, and should be so labelled and handled in such a way that it will not be fed. The dust should be stored where it can not accidentally find its way into food. Handling dusted seed with bare hands causes a skin irritation or burning. In treating seed, work outdoors and on the windward side of the treater, or wear a dust mask or a piece of cloth tied across the mouth and nose to avoid inhaling the dust. If more seed is treated than is needed for planting, hold it over until next year's planting. It should not be crushed for oil. If you are in doubt whether seed has

been treated, the Experiment Station will gladly test a sample for you. This is possible only with seed treated with dust sold in 1941 and subsequently.

Power-driven seed dusters and grader-dusters are commercially available and have been installed at a number of Oklahoma cotton gins for custom service to nearby farmers. Much of the cotton seed entering Oklahoma from other states is already dusted; the label on the seed sack will give that information.

ACID DELINTED SEED

The extremely high quality of acid-delinted seed has been mentioned. Its advantages are: more effective grading; quicker germination that is effective in reducing seedling blight losses; possibility of planting with a corn plate, which results in a greatly reduced seeding rate; and minimizing or even eliminating chopping to thin stands. It is more effective than seed dusting in bacterial blight control. The reduced planting rate alone more than repays the cost of the treatment, and reduced chopping costs and disease-control give a substantial profit on the treatment. In tests made by plant pathologists at the Oklahoma station, acid-delinted, graded seed has repeatedly out-yielded ordinary seed although planted at only $\frac{2}{5}$ the standard seeding rate used for the untreated seed.

Commercial acid-delinted seed has recently appeared on the market and is available through Oklahoma seedsmen. At the reduced planting rate advised by the company which processes the seed, the cost *per acre* of the use of such seed is no greater than the cost of using ordinary gin-run seed at the usual planting rate.

While home-delinting is not ordinarily advised, the following directions are given for growers who might care to undertake the treatment on a small scale:

Cut a wooden barrel in halves. Leave one half with the head intact, and in the head of the other half bore numerous one-inch holes. Then line the head inside with hardware cloth of a mesh small enough to hold back delinted seed. Straddle the perforated tub over a ditch. In the other tub place a bushel of seed and add $\frac{1}{2}$ gallon concentrated sulphuric acid (commercial grade, 66° Baume). Stir with a wooden paddle

5 minutes or until the fuzz has disappeared and the seed mass is black and sticky. Quickly fill the tub with water, loosen the seed mass, and pour into the perforated barrel. At once add more water, washing the seed until the wash water has no more acid taste. Rinse the solid tub and pour the seed back into it, fill with water, and skim off and discard (for planting purposes) the seed that float. Strain the water from the remaining seed, spread out, and dry. They may be dusted with "Ceresan" in a homemade grain- or cotton-seed duster, at a well-invested additional cost of $1\frac{1}{2}$ cents per bushel, which gives protection against soil-borne seedling disease.